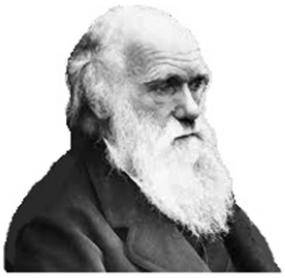
Available online at www.worldnewsnaturalsciences.com



World News of Natural Sciences

An International Scientific Journal

WNOFNS 53 (2024) 203-211 EISSN 2543-5426

Recent progress of the chemical constituents and biological activities of tea stems and tea hairs

Xuan Wang[1], Sheng Tang[1], Jianping Yong[2,a], Yiming Xie[1,b]

[1] College of Materials Science and Engineering, Huaqiao University, Xiamen, China

[2] Xiamen Institute of Rare-earth Materials, Chinese Academy of Sciences, Xiamen, China

[a,b]E-mail address: jpyong@fjirsm.ac.cn , ymxie@hqu.edu.cn

ABSTRACT

Tea is a traditional beverage and originated in China. China is the largest producer of tea in the world. However, during the processing of tea, much tea stems and tea hairs are produced and usually discarded, which results in a large amount of waste. In this minireview, we mainly focused on reviewing the recent progress of chemical compositions and biological activities of tea stems and tea hairs by searching the CNKI, PubMed, Web of Science, Scopus, and Google Scholar databases using “tea hairs and tea stems” as the key words, to provide the good reference for the comprehensive development and utilization of tea stems and tea hairs.

***Keywords*:** Tea stems, Tea hairs, Chemical constituents, Biological activities

1. INTRODUCTION

Tea is the the raw material of traditional drinks, and originated in China for a long history. Tea is also the most popular natural drink in the world, and tea, coffee and cocoa are called as the three major drinks in the world.

In China, the tea culture developped for a long history, and China is the the largest tea production in the world. A thousand years ago, China tea culture sailed from Quanzhou city (Fujian Province of China) to all parts of the world, it makes the China tea popular all over the world. Quanzhou is a famous cultural city and it is also the begaining of the "Silk Road of the

(Received 05 February 2024; Accepted 27 February 2024; Date of Publication 28 February 2024)

Sea". Among them, Anxi county of Quanzhou is the hometown of oolong tea(a world-famous tea). It has been well known as "Southern Fujian Tea Capital" since ancient times, and with the rapid development of tea industry, Anxi gradually has more abundant tea varieties, and it was known as "the treasure house of fine tea varieties".

According to the statistical data, the tea planting areas in Quanzhou reach 790,000 mu to 2019.The areas of mature tea trees reaches 784,100 mu, and the annual raw tea yield is 87,100 Jin. The raw tea yield reaches 93,900 tons in 2021. However, in the process of tea refining, a large number of by-products (such as tea stems, tea hairs) will be produced. These by-products have not been developed and utilized, and often were discarded as the wastes, which will lead to waste of resources. In addition, the putrid tea tea stems, tea hairs also pollute the environment. Therefore, it is very important to explore the value of these discarded rew materials.

It is reported that there are many active natural components (such as tea polyphenols, tea polysaccharides, theanine, caffeine, flavones, etc.). In this mini-review, the chemical components and biological activities of tea stems and tea hairs were comprehensively summarized by searching the CNKI, PubMed, Web of Science, Scopus, and Google Scholar databases using “tea hairs and tea stems” as the key words. This article may provide for the researcher for further development of tea stems and tea hairs. Especially, they are expected to be deeply developed and applied in the fields of daily necessities, drinks, medicines and so on.

2. THE CHENICAL COMPOSITIONS

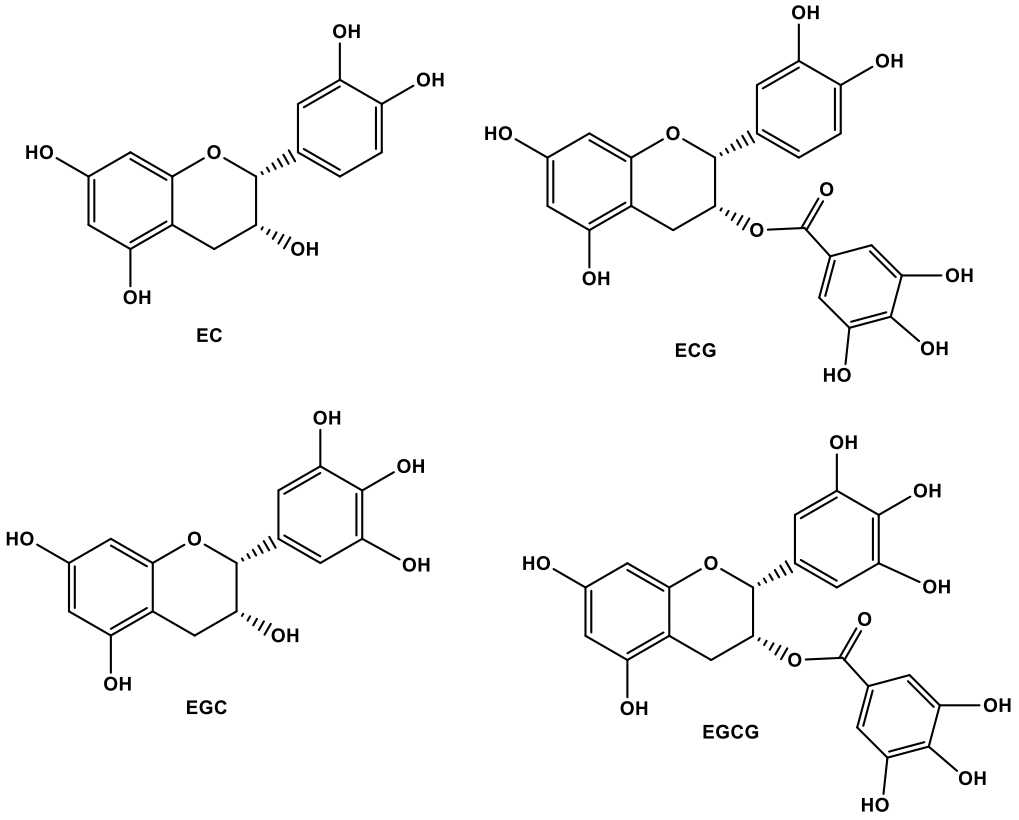
2. 1. Tea polyphenols

Tea polyphenols is generally called as the total polyphenols in tea. The main components of tea polyphenols are flavanones, anthocyanins, flavonols and anthocyanins, phenolic acids and depsidic acids. Among them, flavanones are the key components and account for 60% to 80% of the total tea polyphenols. Catechin can be roughly divided into epicatechin (EC), epicatechin Gallocatechin (EGC), epicatechin-3-gallate (ECG) and epigallocatechin-3-gallate (EGCG), etc. (**Figure 1**) [1]. Tea polyphenols are easily soluble in water and organic solutions, and are the main active components of the tea. According to published data, tea polyphenols have antioxidant, antibacterial, anti-aging and other effects, and are widely used in food, medicine, cosmetics and other fields. Liu Jiaojiao et al [2] studied the extraction and separation technology of tea polyphenols. The extraction technologies of tea polyphenols include solvent extraction, supercritical fluid extraction, microwave-assisted extraction, ultrasonic extraction, etc.; while the separation techniques include: ion precipitation, column chromatography, macroporous adsorption resin method, etc.

2. 2. Tea polysaccharides

Tea polysaccharide is an acidic glycoprotein, which often combines with a large amount of mineral elements, and was called tea polysaccharide complex. The main components of tea polysaccharides are monosaccharides and uronic acids [3]. Tea polysaccharides are insoluble in high concentrations of ethanol, ethyl acetate and other organic solvents. It has poor thermal stability, and it will decompose at the high temperatures. Hu Yan et al [4] found that tea polysaccharide has anti-cancer, antioxidant, hypoglycemic, lipid-lowering effects. Tea polysaccharides are widely used in the adjuvant treatment of diabetes because of their highly effective hypoglycemic effect. The extraction techniques of tea polysaccharides include hot

water extraction, enzymatic extraction, ultrasonic-assisted extraction, microwave-assisted extraction, boiling water extraction, etc; while the separation techniques of tea polysaccharides include gel chromatography, ion exchange chromatography, macroporous resin chromatography, etc. [5].



Figre 1. Strucrures of catechin [1]

2. 3. Theanine

Theanine(structue showed in **Figure 2**) is a peculiar non-protein amino acid of the tea, and it is abundant in the tea, which directly determines the flavor of the tea. Theanine is soluble in water but insoluble in ethanol and ether.

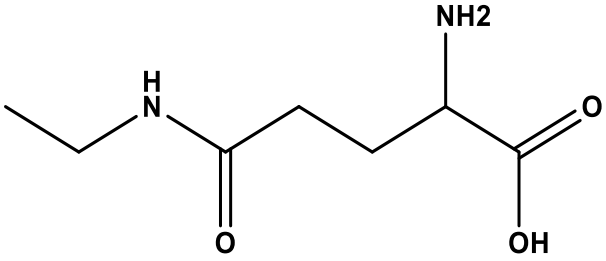


Figure 2. Structure of theanine [6]

Ji Yuanqing etal [7] reported that theanine has beneficial effects on human health: such as lowering blood pressure, protecting brain nerves, and improving immunity. In recent years, theanine [8, 9] has been mainly used in food and beverages, medicines and health care products. The extraction techniques of theanine include: ion precipitation, ultrasonic-assisted extraction, microwave-assisted extraction, etc. Separation techniques [10] include: chromatographic separation, membrane separation, resin chromatography, etc.

2. 4. Caffeine

Caffeine (structure showed in **Figure 3**) is a xanthine alkaloid [11]. Caffeine is a central nervous system stimulant, it can relieve fatigue. It has positive effects such as refreshing, diuretic, and clinically used to treat neurasthenia and coma recovery. However, caffeine also has some side-effects: such as excessive intaking of caffeine can lead to insomnia, increased blood pressure, miscarriage, etc. Therefore, the application of caffeine in food has been forbidded. But it has been shown that theanine can antagonize caffeine and inhibit the excitation of the nervous system caused by caffeine, so that it can reduces the neurological side effects caused by caffeine [12, 13]. According to Xie Jiangbiao reported that caffeine can be used to treat the apnea-related gene polymorphisms in premature infants [14]. The extraction processes of tea include solvent extraction method, ionic liquid extraction method, ultrasonic-assisted method and microwave-assisted method, etc. Separation methods include thin layer chromatography, paper chromatography and so on [15].

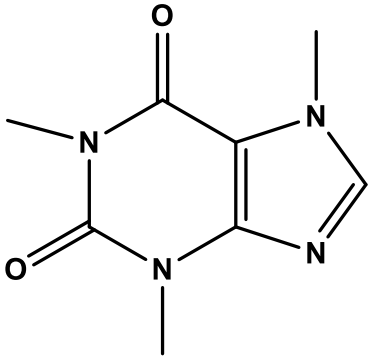


Figure 3. Structure of caffeine [11]

3. THE PROGRESS OF BIOLOGICAL ACTIVITIES

3. 1. Antioxidant

The chemical components with antioxidant properties in tea stems and tea hairs are tea polyphenols, tea polysaccharides, etc. Studies found that although tea polysaccharides have antioxidant properties, the antioxidant properties of tea polysaccharides are lower than that of tea polyphenols. Therefore, the main components of antioxidant activity in tea stems and tea hairs are tea polyphenols.

Chen Zhijie et al. found that the chemical extract in the tea stem has a color-protecting effect on fresh-cut apples to prevent their oxidative discoloration from producing carcinogens, and it has no toxic effect on human body [16]. Jiang Jianwei et al found that tea polyphenols

can significantly inhibit the hemolysis of human red blood cells caused by ultraviolet rays [17]. Wang Yuan et al found that tea polysaccharides in Pu-er can inhibit replicative aging in humans, which may delay cell aging by protecting the mitochondria of aging HDP cells from oxidation [18]. Lin Zhiluan et al [19] found that the scavenging rate of the polysaccharide of Baihao Yinzhen tea hairs at a concentration of 0.22 mg/mL against ▪OH was 38.40%, and the scavenging rate of ▪OH was dose dependent with the the concentration of tea polysaccharide.

3. 2. Prevent and treat diabetes

Diabetes is a common metabolic disorder today. It produces a variety of concurrent symptoms, and it causes a huge threat to human health. Therefore, prevention and treatment of diabetes is very important for the orders. Studies have shown that the main chemical components in the extracts of tea stems and tea hairs regulated blood sugar level are tea polysaccharides and theanine. Yang Guojun found that tea polysaccharides can reduce blood sugar and prevent diabetes by protecting pancreatic β cells, inhibiting the absorption of exogenous carbohydrates, and controlling glucose metabolism enzymes and insulin in the body [20]. Yu Shuchi et al. [21] showed that the polysaccharide extracted from Anji white tea can significantly reduce the blood sugar of the norepinephrine-induced diabetic mice caused by alloxan injection, and the polysaccharide did not affect the glucose tolerance and blood sugar of the testing mice themselves. What's the most important is that the blood sugar-lowering effect of Anji white tea polysaccharide grou was equal to the drug's group. Li et al [22] found that L-theanine could prevent diabetes by enhancing superoxide dismutase activity and inhibiting lipid peroxidation to regulate free radicals. Wan Honggui et al. [23] found that the L-theanine-zinc complex has a significant effect on inhibiting diabetes by lowering blood sugar.

3. 3. Anti-tumor, anti-cancer

It was found that the chemical components (tea polyphenols, tea polysaccharides, theanine, etc.) can be used to prevent tumors. Li Yeyun et al [24] found that tea polyphenols had the preventive effects on tumors and cancers by inhibiting mutation stage, regulating the growth of somatic cells, and inhibiting the growth of cancer cells, inhibiting the metastasis of cancer cells, etc. Hu Xiufang et al [25] found that tea polyphenols can inhibit skin tumors caused by ultraviolet rays mutating the skin.

Cao Mingfu et al [26] studied that *in vivo* antitumor activity of tea polyphenol complexes and the results showed that tea polyphenols could cause tumor cell apoptosis by preventing tumor cell growth during the process. Yuan yong et al [27] found that tea polysaccharides had anticancer effects by promoting the immune cells. Wei nan et al [28] found that tea polysaccharide had synergistic effect with doxorubicin, thereby enhancing the effect of doxorubicin on inhibiting tumor and cancer cells, and reducing the side effects of doxorubicin. It is reported that although theanine could not directly inhibit the cancer cell lines, it can enhance the effect of anti-cancer drugs by inhibiting the infiltration of cancer cells to prevent the spread of cancer cells, and reduce the side effects of drugs [29, 30].

3. 4. Anti-inflammatory

Inflammation is very comman, and it can cause many related diseases. Therefore, we should pay attention to its impact on the human body. It has been confirmed that tea has a significant effect on anti-inflammatory by regulating various inflammatory factors. Many

chemical components of tea (sucha as tea polysaccharides, theanine, etc.) have anti-inflammatory activity, while tea polyphenols are more potent that other components. Zhao hangye et al [31] studied the anti-inflammatory mechanism of tea polyphenols and found that tea polyphenols could effectively promote the proliferation of fibroblasts, promote the production of collagen, inhibit the reproduction of wound bacteria, etc., thereby inhibiting the occurrence of infectious inflammation in wounds.

Xu Mingxian et al [32] found that tea polyphenols could reduce the content of pro-inflammatory factors in the liver, thereby reducing the acute liver injury induced by lipopolysaccharide. Xu Lingling et al [33] found that tea polysaccharides could reduce colon inflammation by feeding tea polysaccharides to mice suffering from ulcerative colitis induced by dextran sulfate sodium. Gao Qiang et al. [34] found that theanine could reduce the inflammation and acute liver injury caused by lipopolysaccharide. Shibakusa et al [35] found that oral theanine for the surgical mice could inhibit the increase of inflammatory cytokines in blood.

3. 5. Antibacterial

In daily life, bacteria are everywhere, and bacteria are invisible to our naked eyes. Some of them are both useful, while some of them are harmful to our life. Just like the probiotics in yogurt, it can help the bowel to move and aid digestion. However, some bacteria(such as Staphylococcus aureus and Escherichia coli) will become pathogens and cause harm to human beings [36].

It has been found that tea polyphenols, tea polysaccharides, theanine, etc. can inhibit the growth of bacteria, and the bacteriostatic agents composed by these components are very efficient and environmentally friendly. Li Qisong [37] developed an effective natural fruit compound preservative containing tea polyphenols, which can inhibit the growth *of Escherichia coli*, *Bacillus subtilis* and *Staphylococcus aureus*. Diao Chunhua et al. [38] prepared the liquid soap containing tea extract and found that this liquid soap had better anitbacterial activities than the soap on the market. Song Shanshan et al. [39] found that Meitan white tea polysaccharides had good *in vitro* antibacterial activity and stability. Wang Furong [40] et al. found that tea polyphenols and theanine had a certain inhibitory effect on Escherichia coli and Staphylococcus aureus.

4. CONCLUSION

As a natural health drink, tea is increasingly valued. However, during the processing of tea, much tea stems and tea hairs are produced and usually discarded, which results in a large amount of waste. While people pay more and more attention to green environmental protection, the chemical components in tea stems and tea hairs have been developped and used in the fields of beverages, cosmetics, medicines and health products.

Our group has taken the lead to study the tea hairs and tea stems, and obtained good results [41-44]. However, in order to promote its development and utilization, much research should be carried out based on the following aspects: (1) further research on the isolation of their chemical compotents, biological acticities should be carried out; (2) the residues of extracted tea stems and tea hairs can be explore for biomass carbon materials. This review article provide the good reference for the researchers.

Acknowledgment

This work was financially supported by Science and Technology Planning Program of Xiamen (Nos. 2022CXY0702; 2023CXY 0701).

References

[1] Chen L , Yin LG , Zhang C, et al. (2022.) Review on the application of tea polyphenols in fermented foods. *Food and Fermentation Industry* 49(2): 1-10

[2] Liu JJ. (2022) Research progress on extraction and separation technology of tea polyphenols in tea. *Fujian Tea* 44(5): 29-31

[3] Weng W , Li SK , Zhang QM, et al. (2021). Research progress of composition and health function of tea polysaccharides. *Chinese Journal of Traditional Chinese Medicine* 36(12): 7261-7264

[4] Hu Y. (2022). The efficacy of organic acids and tea polysaccharides in tea and their research progress in Ya'an Tibetan tea. *Agricultural product quality and safety* (4): 23-27

[5] Cheng LiZ, Zhu JX, Zhou H, et al. (2021). Research progress on extraction, purification, structures, activities and application of tea polysaccharides. *Chinese Tea* 43(8): 7-15

[6] Wang XH , Liang HL , Mao BY, et al. (2021). The Current Situation and Prospect of the Utilization of Theanine. *Chinese Tea* 43(3): 6-10

[7] Ji YQ , Zhou YH , Zhang T, et al. (2022). Production technology of L-theanine and its application prospect. *Food and Fermentation Industry* 48(24): 303-311

[8] Yang Z. (2018) Research progress in the Healthy Functions of Theanine. *Tea Newsletter*, 45(2): 3-7

[9] Zhang Y , Shi ZP , Shi L. (2003). Progress in studies of theanine.*Natural Product Research and Development* 15(4): 369-372

[10] Ge Y. (2013) Extraction, isolation and purification of theanine from summer-autumn green tea and its influence on intestinal microecology. Master Thesis. Nanjing Agricultural University.

[11] Yang JY , Lian YH , Hu XD, et al. (2022). Sipping tea: General introduction of the organic components in tea. *University Chemistry* 37: 1-5

[12] Yu H , Ma JH , Ding YF, et al. (2012). Analysis of the antagonistic mechanism of theanine on the stimulant effect of caffeine. *Chinese Journal of Drug Dependence* 21(4): 260-263

[13] Li CJ , Luo L , Huang CH. (2019). Research progress on neuroprotective effects of L-theanine. *Hunan Journal of Traditional Chinese Medicine* 35(12): 147-151

[14] Xie JB , Lin XZ. (2022). Recent research on gene polymorphisms related to caffeine therapy in preterm infants with apnea of prematurity. *Chinese Journal of Contemporary Pediatrics* 24(7): 832-837

[15] Wang WQ , Xu XM , Zhang YJ. (2020). Research progress on extraction technology of caffeine from tea leaves. *Sichuan Chemical* 23(6): 17-19

[16] Chen ZJ. (2021). Color protection of fresh cut apple by extract from tea stem. *Journal of Wuyi University* 40(9): 6-10

[17] Jiang JW , He WS , Yan YX, et al. (1999). A study of Protective action of tea polyphenols on damage cell membrane and DNA induced radical. *Journal of Chinese Physicians* 1(6): 19-21

[18] Wang Y , Rong H , Chu XH, et al. (2015.) Effects of natural Anti-aging mechanism of Pu'er tea extract and Pu'er tea polysaccharide on human fibroblasts. *Journal of Yunnan Agricultural University (Natural Science)* 30(2): 219-227

[19] Lin ZL, Wang H, Zheng XZ, et al. (2015). Optimization extraction process of polysaccharide from hairs of Baihaoyinzhen and its antioxidation. *Hubei Agricultural Science* 54(3): 665-668

[20] Yang JG , Wang LL , Chen L. (2018). Research progress on pharmacological activities of polysaccharides prepared from tea. *Food Industry Technology* 39(6): 301-307

[21] Yu SC , Liu C , Wang CH, et al. (2012). Antioxidant activity of tea polyphenols in Anji white tea. *Shizhen Traditional Chinese Medicine* 23(5): 1184-1187

[22] Li G, Ye Y, Kang J, et al. (2012). L-Theanine prevents alcoholic liver injury through enhancing the antioxidant capability of hepatocytes. *Food Chemistry Toxicology* 50 (2): 363-372

[23] Wan HG, Peng YC, Huang ZX, et al. (2014). Progress in the relations of zinc compounds with Zn(N_2O_2) coordination mode and L-theanine-zinc with diabetes mellitus. *Chinese Journal of Pharmacology and Toxicology* 28(5): 774-778

[24] Li YY , Jiang CJ , Wang XL. (2002). Research progress on biological activity and pharmacology of tea polyphenols. *Journal of Anhui TCM College* 21(5): 57-60

[25] Hu XF, Yang XQ, Chen LJ. (2000). The protective and therapeutic effect of tea polyphenols on skin. *Fujian Tea* 2: 44-45

[26] Cao MG , Shao HQ. (1999). Tea polyphenol complex inhibits tumor and its effect on cellular immune function. *Pharmaceutical Biotechnology* 6(4): 212-217

[27] Yuan Y , Yin Z , Tan YP, et al. (2018). Advances in extraction, separation and biological activity of tea polysaccharides. *Tea Newsletter* 45(3): 8-12

[28] Wei N , Zhu QQ , Chen JM, et al. (2016). Tea polysaccharide increased doxorubicin inhibition of lung cancer A549 cells. *Tea Science* 36(5) :477-483

[29] Zheng N. (2019). Analysis on the physiological health care function of theanine. *Fujian Tea* 41(7): 25

[30] Gao P, Hu LY, Meng PP, et al. (2010). Antineoplastic effect and mechanism of theanine. *Journal of Guangdong University of Pharmacy* 26(5): 533-536

[31] Zhao HY, Xia C, He PM, et al. (2021). Effects of tea polyphenols on anti-inflammation and promotion of wound healing and its mechanisms. *Journal of Zhejiang University (Agriculture and Life Sciences Edition)* 47(1): 118-126

[32] Xu MX , Zhang JR , Tang RD, et al. (2020). Comparative study on the effects and mechanism of L-carnitine and Tea-polyphenols on acute liver injury induced by lipopolysaccharide in mice. *Journal of Practical Medicine* 36(6): 711-715

[33] Xu LL , Cheng WK , Zhou XN. (2021). Regulatory effect of Pu-erh tea polysaccharide on short-chain fatty acid metabolism and gut microbiota in mice. *Food and Fermentation Industry* 47(21): 115-122

[34] Gao Q. (2019.) Protective effect and mechanisms of green tea and its characteristic components on various hepatic inflammation models in mice. Master Thesis. Anhui Agricultural University.

[35] Shibakusa T, Mikami T, Kurihara S. (2012). Enhancement of postoperative recovery by preoperative oral co-administration of the amino acids, cystine and theanine, in a mouse surgical model. *Clin Nutr* 31: 555-561

[36] Zeng YW. (2020) Evaluation of antibacterial activity of 20 kinds of edible flower tea. *Tropical Agricultural Science* 40(4): 56-61

[37] Li QS , Li JJ , Ye JH, et al. (2021). Antibacterial activity of tea polyphenols and its application in fruit compound preservative. *Fujian Agricultural Science and Technology* 52(10): 22-26

[38] Diao CH. (2018). Study on bacteriostatic hand sanitizer with Tea bioactive ingredients. Master Thesis. Zhejiang Agriculture and Forestry University.

[39] Song SS, Yang AH, Wang XM, et al. (2021). Antibacterial activity and stability of polysaccharides from Meitan white tea on Staphylococcus aureus. *Food Industry Technology* 43(3): 114-119

[40] Wang FR, Li WP, Ma MH. (2006). Study on the Antibacterial Effects of Four Extracts from Natural Plants. *Chinese Journal of Veterinary Medicine* 40(2): 23-25.

[41] Xiao YC, Yong JP, Lu CZ (2021). Study on the effective chemical components extracted from the tea stems and tea hairs and their antioxidant activity. *Acad. J. Med. Plants*. 9(10): 161-165

[42] Yong JP, Lu CZ, Xiao YC, et al. (2021). An extract of active parts of tea waste and its extraction method and use. *Chinese Patent* 202110902714.1 (Application Number).

[43] Xie YM, Chen HX, Lu CZ, et al. (2021). A phosphorus and nitrogen doped biomass hard carbon material and its preparation method and application. *Chinese Patent* 202110908449.8 (Application Number).

[44] Wang HY, Chen HX, Chen C, et al. (2022). Tea-derived carbon materials as anode for high-performance sodium ion batteries. *Chin Chem Lett.* 63(4): 1-8